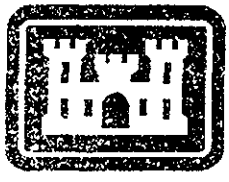
NEW HAMPSHIRE FLOOD PLAIN MANAGEMENT SERVICES

HORN POND
DAM-BREACH FLOOD ANALYSIS
WAKEFIELD, NEW HAMPSHIRE &
NEWFIELD, MAINE

March 1999



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New England District

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This report presents the findings of a dam-breach flood analysis performed for Horn Pond Dam. The dam is owned, operated, and maintained by the New Hampshire Department of Environmental Services, Water Resources Division. Included in the report is a description of pertinent features of the dam, procedures used for the analysis, assumed dam-breach conditions, and the resulting effect on downstream flooded areas, particularly the town of Milton. This study was not performed because of any known likelihood of a dam-breach at this dam. The purpose is to provide information for emergency planning use. The dam-breach flood analysis was conducted at the request of the state of New Hampshire, under the authority of the Corps of Engineers Section 206 Flood Plain Management Services (FPMS) program. The report presents the findings of a dam-breach analysis performed assuming flood (estimated March 1936, flood of record) conditions initially occuring within the watershed.

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HORN POND
DAM-BREACH
FLOOD ANALYSIS

Wakefield, New Hampshire
and
Newfield, Maine

PREPARED FOR:

State of New Hampshire
Department of Environmental Services
Water Resources Division

PREPARED BY:

Water Management Section
Geotechnical and Water Management Branch
Engineering/Planning Division

Department of the Army
New England District, Corps of Engineers
Concord, Massachusetts

March 1999

Horn Pond Dam
Dam-Breach Flood Analysis

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Horn Pond Dam
Dam-Breach Flood Analysis

1. PURPOSE

This report presents the findings of a dam-breach flood analysis performed for Horn Pond Dam. The dam is owned, operated, and maintained by the New Hampshire Department of Environmental Services, Water Resources Division. Included in the report is a description of pertinent features of the dam, procedures used for the analysis, assumed dam-breach conditions, and the resulting effect on downstream flooded areas, particularly the town of Milton. This study was not performed because of any known likelihood of a dam-breach at this dam. The purpose is to provide information for emergency planning use.

The dam-breach flood analysis was conducted at the request of the state of New Hampshire, under the authority of the Corps of Engineers Section 206 Flood Plain Management Services (FPMS) program. This report presents the findings of a dam-breach analysis performed assuming flood (estimated March 1936, flood of record) conditions initially occuring within the watershed.

2. MODEL DESCRIPTION

A dam-breach analysis for Horn Pond Dam was conducted using Boss Corporation's 1992 release of the National Weather Service Dam-Breach Flood Forecasting Computer Model developed by D.L. Fread. Input for the model consists of storage characteristics of the reservoir, selected geometry and duration of breach development, and hydraulic roughness coefficients for the downstream channel. Detailed descriptions of this data are discussed later in this report. Based on input data, the model computes the breach outflow hydrograph and routes it downstream. The analysis provides output on the attenuation of the flood hydrograph, and timing of the flood wave as it progresses downstream. These results are also discussed in detail.

3. DESCRIPTION

a. General. The Salmon Falls River originates in Wakefield, NH and flows south for approximately 39 miles along the Maine-New Hampshire border through Milton, East Rochester, and Dalton, NH to its confluence with the Cocheco River to form the Piscataqua. A significant tributary in the study area is the Branch River which originates in Brookfield, NH and flows southeast for 16 miles through Middleton and Milton, NH to its confluence with the Salmon Falls River, approximately 10.4 miles downstream of Horn Pond Dam. Another tributary, Miller Brook, originates in Wakefield, NH and flows southeast for 3 miles to its confluence with the Salmon Falls River in Milton, NH, approximately 6.4 miles downstream of Horn Pond Dam. The topography of the drainage area is rolling terrain and is heavily wooded.

The study extended from Horn Pond Dam in Wakefield, NH, downstream along the Salmon Falls River, through Hopper Street, Church Street, School Street, Milton Three Ponds, and Milton Leather Board Dams for a distance of approximately 15.1 miles. The drainage area contributing to the study reach increases from 22.8 square miles at Horn Pond Dam to 108.0 square miles at Milton Three Ponds Dam. The total study reach is shown on Plate 1.

b. Horn Pond Dam. Horn Pond Dam is located on the southern end of the impoundment, across the Maine-New Hampshire state line in Wakefield, New Hampshire and Newfield, Maine. The location of Horn Pond Dam is shown on Plate 1. It is one of the upstream dams in a series of dams which impound the waters of the Salmon Falls River. The surrounding land is heavily wooded with rolling terrain. The total drainage area of Horn Pond is 22.8 square miles.

Horn Pond Dam is a concrete gravity dam, approximately 77.5 feet long, with a hydraulic height of 14' +/- above streambed and top of dam elevation of 557.6 feet NGVD (highest elevation). The dam consists of two regulating sets of stoplog bays; 8 bays on the right looking downstream, and 3 bays on the left. The stoplogs are normally set to maintain a normal pool of 554.2 ft. NGVD.

Table 1

Pertinent Data
Horn Pond Dam

a. Drainage Area. Horn Pond Dam controls a drainage area of approximately 22.8 square miles consisting of rolling to steeply sloping terrain.

b. Elevations (feet NGVD)

(1) Top of dam - 556.8 to 557.6 (sloping dam crest)
(2) Spillway crest - 554.2 (top of stop logs)

c. Reservoir Surface Area (acres)

(1) Spillway crest - 229 acres
(2) Top of dam - 264 acres

d. Dam

(1) Type - concrete gravity dam
(2) Length - 77.5 feet
(3) Height - 14+/- feet above streambed
(4) Topwidth - varies
(5) Side Slopes
upstream varies: vertical
downstream varies: varies
(6) Impervious core - none

by excavating a ditch to start the flow of water [illegible]

(7) Cutoff - unknown
(8) Grout curtain - unknown

e. Regulating Outlet

(1) Invert - 543.9 feet NGVD
(2) Size - 8 bays @ 5.5' wide, 3 bays @ 4.5' wide
(3) Description - 11 stoplog bays
(4) Control - wooden stoplogs

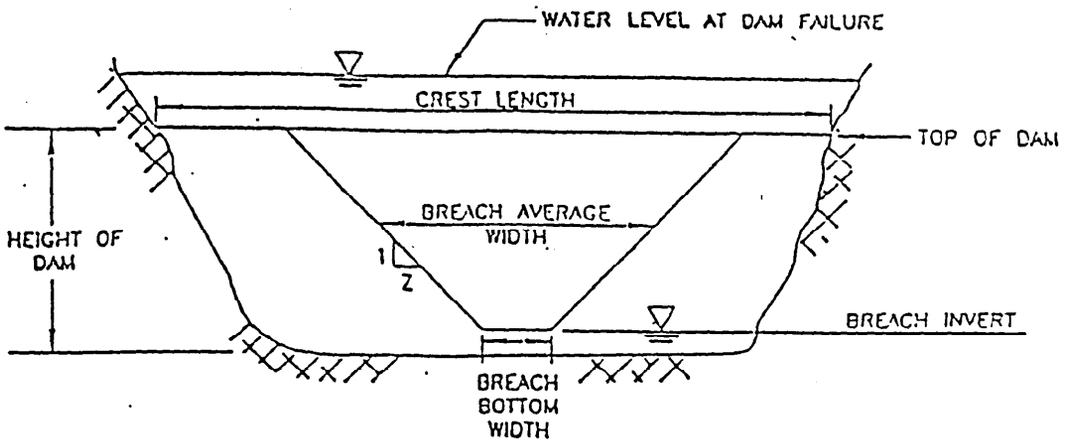
c. Downstream Valley. Downstream of Horn Pond, the channel slope is relatively steep averaging 51 feet per mile. There are several small flow structures and road crossings across the Salmon Falls River between Horn Pond and the beginning of Milton Three Ponds (Milton, Townhouse, and Northeast Ponds), approximately 9 miles downstream. When the river enters Milton Three Ponds, the valley widens and becomes relatively flat with an average slope of 6 feet per mile. A concrete gravity dam located at the end of Milton Three Ponds (14.8 miles D/S of Horn Pond Dam) is 19 feet high and 200 feet long. The river valley downstream of Milton Three Ponds Dam is steep to Spaulding Pond averaging approximately 100 feet per mile.

A minimum number of detailed surveys of the river channel and crossings were performed as part of this study. These were supplemented with surveys and cross section information obtained from Flood Insurance Studies for the towns of Milton and Rochester, NH.

4. METHOD OF ANALYSIS

a. General. This section discusses the methods and assumptions used in the dam-breach analysis. The magnitude of a flood resulting from a hypothetical dam-breach depends not only on the size of the project but also on the conditions of failure including the initial level of the reservoir, size of the breach, rate of breach formation, as well as hydraulic features and initial flows in the downstream river channel. The state of New Hampshire has adopted a criteria for the initial reservoir inflow prior to failure to be equal to the flood of record in the watershed where the dam is located. At Horn Pond the flood of record is the March 1936 event. That discharge together with appropriate discharges from downstream uncontrolled drainage areas is used as the initial flow prior to dam failure.

b. Assumed Breach Parameters. The discharge hydrograph of a breach is a function of the inflow hydrograph and breach parameters (time of breach formation, size, and shape of breach) of a hypothetical dam failure. The following sketch illustrates the various dam breach parameters for a typical earthen or concrete-gravity dam. Total outflow is a combination of flows through the breach and spillway. As the breach develops, so does the breach discharge.



DEFINITION SKETCH OF BREACH PARAMETERS

Assumed Horn Pond Dam Failure Condition

Est. Reservoir Outflow: 750 cfs (est. March 1936 flow)

Pool Level at Failure: 557.6 feet NGVD
(top of dam)

Breach Invert: 543.9 feet NGVD
(toe of dam)

Breach Bottom Width: 77.5 feet with side slopes 1V:0H

Time to Complete Formation of Breach: 0.5 hours

Downstream Reach Roughness
(Manning's "n" Values): 0.029 to 0.12

Prebreach Downstream Lateral Inflow: Estimated March 1936 flood flows

c. Assumed Prebreach Flows. Assumed pre-breach flows on the Salmon Falls River for the dam failure simulation were developed for the downstream watershed. These are the assumed flows from antecedent conditions that would be expected to occur with or without a dam failure. Based on hydrologic conditions of the downstream watershed, lateral inflows, representing contributing flow from downstream tributaries and local runoff areas, were included at river miles 7.9, and 12.2 (stationing is in river miles downstream of Great East Lake Dam and Horn Pond

Dam is at river mile 1.65). The contributing net drainage areas at river miles 7.9 and 12.2 were 3.1, and 57.0 square miles.

The discharge from Horn Pond Dam was added to lateral inflows at downstream points equal to the estimated March 1936 flows. With the adopted pre-breach conditions at the dam, due to uncontrolled spillway discharge and downstream inflows associated with these rare events, downstream channel capacities would have been exceeded and flooding would have occurred prior to a dam-breach.

d. Downstream Channel Routing. A downstream channel routing analysis allows the breach discharge hydrograph to be characterized at points of interest below the dam. The downstream channel stationing is in river miles below Great East Lake Dam, with river mile 0.0 at the dam. The stationing was adopted to allow for comparison between the Great East Lake Dam-Breach Analysis and the Horn Pond Dam-Breach Analysis, and to help estimate initial flow conditions in the watershed. A breach hydrograph is attenuated and stored through the downstream channel and flood plain. The degree to which this breach discharge is attenuated is a function of the downstream valley storage capacity and valley roughness characteristics.

The dynamic wave method of channel routing is used in the NWS DAMBRK computer program to route the flood wave downstream. This is a hydraulic routing method that solves the complete unsteady flow equations through a given reach. Results of this method indicate attenuation of the flood wave, resulting flood stages, and the time it takes the wave to reach a section of the river.

Downstream valley data were determined by obtaining selected cross sections from HEC-2 input files from Milton and Rochester, NH Flood Insurance Studies. On the average, approximately three cross sections per mile were used to represent the downstream valley. Manning's "n" values were assigned to the channel and overbanks on the basis of the HEC-2 analysis and field observations. Discharge and stage hydrographs were selected at six downstream stations, river miles 1.65, 6.7, 7.8, 8.3, 16.4, and 16.7 (as shown in Plate 9). The locations of twenty cross sections are shown on Plates 2 and 3. These twenty were selected to characterize the movement and attenuation of the dam-breach flood wave as it progresses downstream.

The geometry input to define the downstream channel does not include detailed bridge information. This study does not attempt to determine if any downstream structures will or will not fail during a dam-breach at Horn Pond Dam. For this study, the dam structures were modeled as remaining intact. This approach was viewed as the most conservative one, resulting in higher peak water surface elevations behind them than if the dams were breached.

State of New Hampshire during the period 1955-1957

5. RESULTS OF ANALYSIS

a. General. This section discusses results of the dam failure analysis at Horn Pond Dam. The results presented assume that the impoundment water surface elevation is at the top of dam with full spillway discharge occurring, and that the dam-breach flood is superimposed on pre-breach flood flow within the downstream channel reaches.

b. Inflow Hydrograph. The peak outflow from Horn Pond Dam resulting from the March 1936 storm event was assumed to be 750 cfs. This outflow was estimated from a previous study at Great East Lake which estimated the March 1936 outflow to be 600 cfs, along with 150 cfs from the contributing drainage area below Great East Lake Dam, and upstream of Horn pond Dam. The drainage area ratio analysis of the flow records for March 1936 at the USGS gaging station on the Salmon Falls River at East Lebanon, Maine was used for the initial estimates of flow.

c. Reservoir Storage Capacity. Surface areas for Horn Pond were obtained from USGS Quad sheets (1:24000, 20-foot contour).

d. Breach Discharge Hydrograph. Table 2 summarizes the peak discharge and downstream channel routing results at selected cross sections.

The failure at Horn Pond Dam resulted in a peak breach discharge of approximately 12,800 cfs. The assumed water surface was at the top of the dam, elevation 557.6 feet NGVD when failure began, and the breach was modeled to develop fully within 0.5 hours. Plates 4 - 8 show the pre-breach and dam-breach flood profiles for the study reach; Plate 9 shows the breach discharge and stage hydrographs for selected cross sections throughout the reach. Plate 10 shows how the breach flood peak discharge varies with distance downstream.

TABLE 2
Horn Pond Dam Failure
Downstream Channel Routing Results

Downstream Location (River Miles)	Peak Discharge (cfs)*	Peak Elevation (ft NGVD)	Time to Peak Elevation (hours)**	Prebreach Flow Elevation	Increase in Depth of Flow (feet)
Horn Pond Dam (1.65)	12800	557.6	0.0	557.6	0.0
3.7	11000	517.6	1.1	512.0	5.6
4.1	10340	511.2	2.6	508.0	3.2
Hopper Street Dam (6.7)	4030	509.3	4.7	506.6	2.7
Church Street Dam (7.6)	4030	455.5	4.9	452.5	3.0
School Street Dam (7.8)	4030	438.2	5.5	436.2	2.0
12.2	4070	421.5	30.0	419.1	2.4
Milton Three Ponds Dam (16.4)	7600	421.2	30.0	418.9	2.3
Milton Leather Board Dam (16.7)	7600	403.5	30.0	402.4	1.1

* Includes inflow from downstream watersheds
** Time to peak measured from start of breach at Horn Pond Dam

6. DOWNSTREAM CHANNEL ROUTING

Plates 4 - 8 show peak water surface profiles resulting from the pre-breach initial flow and failure flow. The peak dam-breach discharge computed by the DAMBRK computer program is about 12,800 cfs. Ths flow results in a stage increase of about 9.5 feet over the prebreach high flow downstream of the dam at cross section 2.3. The peak breach discharge attenuates to about 5,800 cfs at river mile 5.1, and increases to 7597 cfs at rivermile 16.4 due to high pre-breach initial flows. The breach flow would overtop Milton Three Ponds Dam by approximately 3.5 feet. At areas below this point, peak stages would only be about 1.0 feet above the assumed pre-breach flows.

The dams located downstream of Horn Pond Dam within the study reach are Hopper Street Dam (RM 6.7), Church Street Dam (RM 7.6), School Street Dam (RM 7.8), Milton Three Ponds Dam (RM

16.4), and Milton Leather Board Dam (RM 16.7). The intent of this study is not to determine if, or when, these dams would fail. The adopted dam-breach conditions assume that these dams remain. The water level could get several feet above the top of the dams before it fails. Therefore, the worst case scenario (assuming these dams do not fail) was used in the final results presented in the tables and various plots to get an indication of the maximum potential levels and inundation that could occur.

The analysis was conducted in one reach from Horn Pond Dam (RM 1.65) to downstream of Milton Leather Board Dam (RM 16.74). The time to peak elevation, as shown in Table 2, is an important factor in determining emergency evacuation procedures. As mentioned previously, Horn Pond Dam was assumed to fail in 0.5 hours and due to topographic and physical features the maximum breach width would be in the order of 78 feet.

A rapid failure (0.5 hours) of the 14+/- feet high dam results in a fast rise to a peak discharge of about 12,800 cfs. However, as time progresses the major portion of the breach hydrograph has discharged from the relatively small storage capacity of the pond in the first 5 hours after failure. Discharge and stage hydrographs throughout the reach are shown on Plate 9.

From Horn Pond Dam (RM 1.65) to School Street Dam (RM 7.8) the time to peak stage increases from 0.0 hours to 5.5 hours. In the reach from School Street Dam (RM 7.8) to the beginning of Milton Three Ponds (RM 12.2) the peak time increases from 5.5 hours to 30.0 hours. The channel downstream of School Street Dam changes from having a gradual slope to having a flat profile at RM 12.2, and the valley widens significantly at RM 12.2 due to the large surface area of Milton Three Ponds. The changes in the valley characteristics along with Milton Three Ponds Dam (RM 16.4) drop the flow velocity from 5.4 feet per second at School Street Dam to less than 1.0 foot per second throughout Milton Three Ponds resulting in the significant increase in the time to peak stage. Discharge and stage hydrographs for this reach are shown on Plate 9. We note that the flood wave progresses downstream at a relatively slow speed therefore time to peak stage is long. This is attributed mainly to the flat slope and floodplain storage along the Salmon Falls River.

The increase in the dam-breach flood over the assumed pre-breach flood levels is an indication of the flooding that can be expected as a result of a dam-breach. It is again noted, that the assumed pre-breach flood conditions are rare conditions, and there would be flooding prior to failure. These pre-breach high flows are due to uncontrolled spillway discharges at the dam, along with downstream lateral inflows and not attributable to a dam failure.

7. INUNDATION MAPPING

The limits of inundation were computed by routing the breach discharge hydrograph through the downstream valley cross sections and delineating the resulting maximum stages on the base map. The base map used is based on a 20-foot contour interval 1:24,000 scale USGS quadrangle and, therefore, inundation limits shown on Plates 2 and 3 are only approximate. Inundation mapping with a larger scale of 1":1,000' is provided in Appendix I. Locations of the twenty selected downstream stations are graphically illustrated on Plates 2 and 3. Although any structures shown within these limits were assumed to be inundated, certain structures may be excluded as a result of local conditions and elevations.

8. DISCUSSION

The dam-breach analysis for Horn Pond Dam was based on engineering application of certain laws of physics, considering the physical characteristics of the project and downstream channel and conditions of failure. Due to the highly unpredictable nature of a dam-breach and the ensuing sequence of events, the results of this study should not be viewed as exact but only as an approximate quantification of the dam-breach flood potential. For purposes of analysis, downstream conditions are assumed to remain constant, and no allowance is made for possible enlargement or relocation of the river channel due to scour or temporary damming effects, all of which could affect, to some extent, the resulting magnitude and timing of flooding.

The results of a dam failure could be damaging at areas downstream of the dam. However, for the adopted pre-breach flows, due to uncontrolled spillway discharges and downstream inflows associated with these rare events, channel capacities would have been exceeded and flooding would have occurred prior to a dam-breach at the dam. It should be noted that a dam failure occurring during a more frequent (less severe) event would result in a more prominent rise over pre-breach flood levels. However, the peak breach levels and flooded areas would be less than the adopted results.

Also, this study does not attempt to determine if any downstream structures will or will not fail during a dam-breach at Horn Pond Dam. For this study, the dam structures were modeled as remaining intact. This approach was viewed as the most conservative one, resulting in higher peak water surface elevations behind them than if the dams were breached.

The dam-breach analysis ended on the Salmon Falls River, about fifteen miles downstream of Horn Pond. The state of New Hampshire's criteria for ending dam-breach analyses is to compute the water surface elevation downstream of the dam until the breach water surface elevations are within 2.0 feet of the pre-breach water surface elevations. Horn Pond dam failure flows are within 2.0 feet of pre-breach flow levels downstream of Milton

Three Ponds dam (river mile 16.4) to river mile 16.74 (end of the analysis).

supplemented with plans and specifications are

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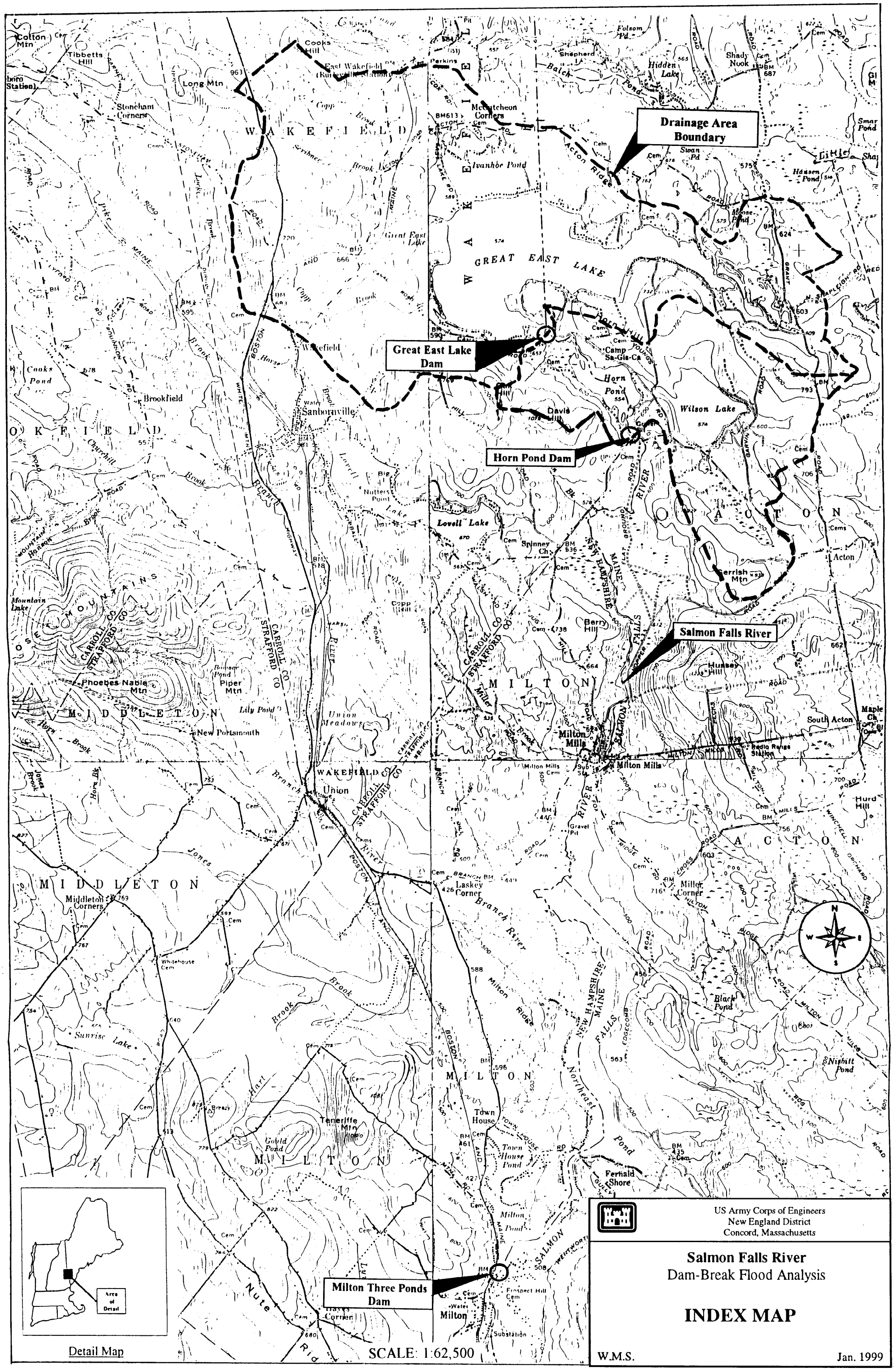


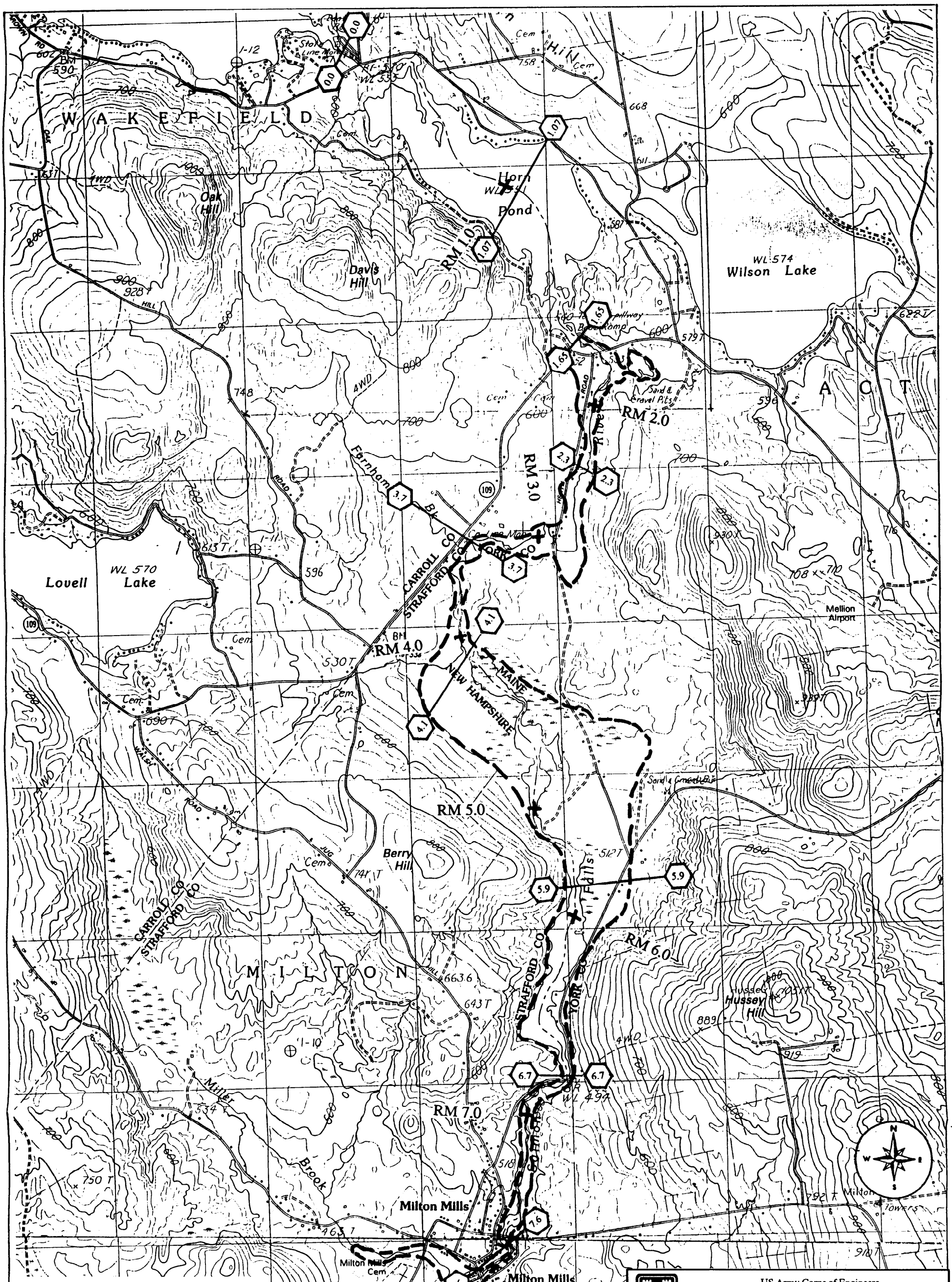
US Army Corps of Engineers
New England District
Concord, Massachusetts

Salmon Falls River
Dam-Break Flood Analysis

INDEX MAP

W.M.S. Jan. 1999

PLATE 1



LEGEND

- Horn Pond
- Dam-Breach Inundation Limits
- Cross Section Location
- + RM — River Miles Downstream From Great East Lake Dam

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New England District
Concord, Massachusetts

Salmon Falls River
Dam-Break Flood Analysis

INUNDATION MAPPING
Sheet 1 of 2

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PLATE 2

Match Line - Sheet 1

RM 9.0
RM 10.0
RM 11.0
RM 12.0
RM 13.0
RM 14.0
RM 15.0
RM 16.0

Laskey Corner
Miller Corner
Town House
Town House Pond
Milton
Milton Pond
WL413
Black Pond
Fernald Shore
Trailer Park
Prospect Hill Cem
Campground
Milton Ridge
MILTON
SALMON FALLS RIVER
NORTHEAST POND
BRANCH
BOSTON AND MAINE
NEW HAMPSHIRE MAINE
4WD
Swamp
Cem
BM 445.9
BM 716.3
BM 596.4
BM 460.6
BM 435.7

LEGEND

Horn Pond Dam-Breach Inundation Limits

Cross Section Location

+ RM River Miles Downstream From Great East Lake Dam

US Army Corps of Engineers
New England District
Concord, Massachusetts

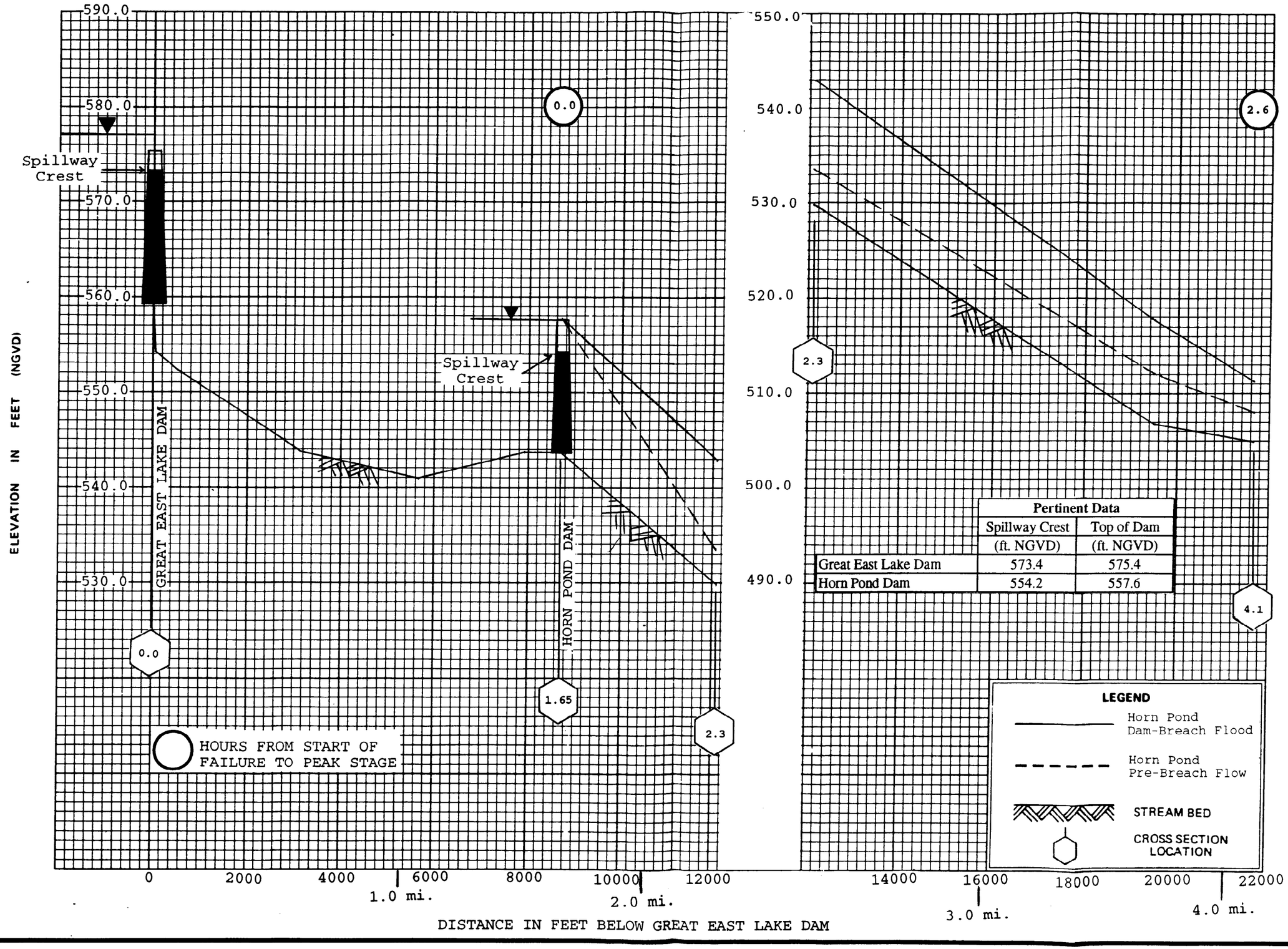
Salmon Falls River
Dam-Break Flood Analysis

INUNDATION MAPPING
Sheet 2 of 2

W.M.S. Jan. 1999

SCALE: 1":2,000' Contour Interval 20 Feet

PLATE 3



FLOOD PROFILES

SALMON FALLS RIVER - PROFILE #1

HORN POND DAM
DAM-BREACH FLOOD ANALYSIS

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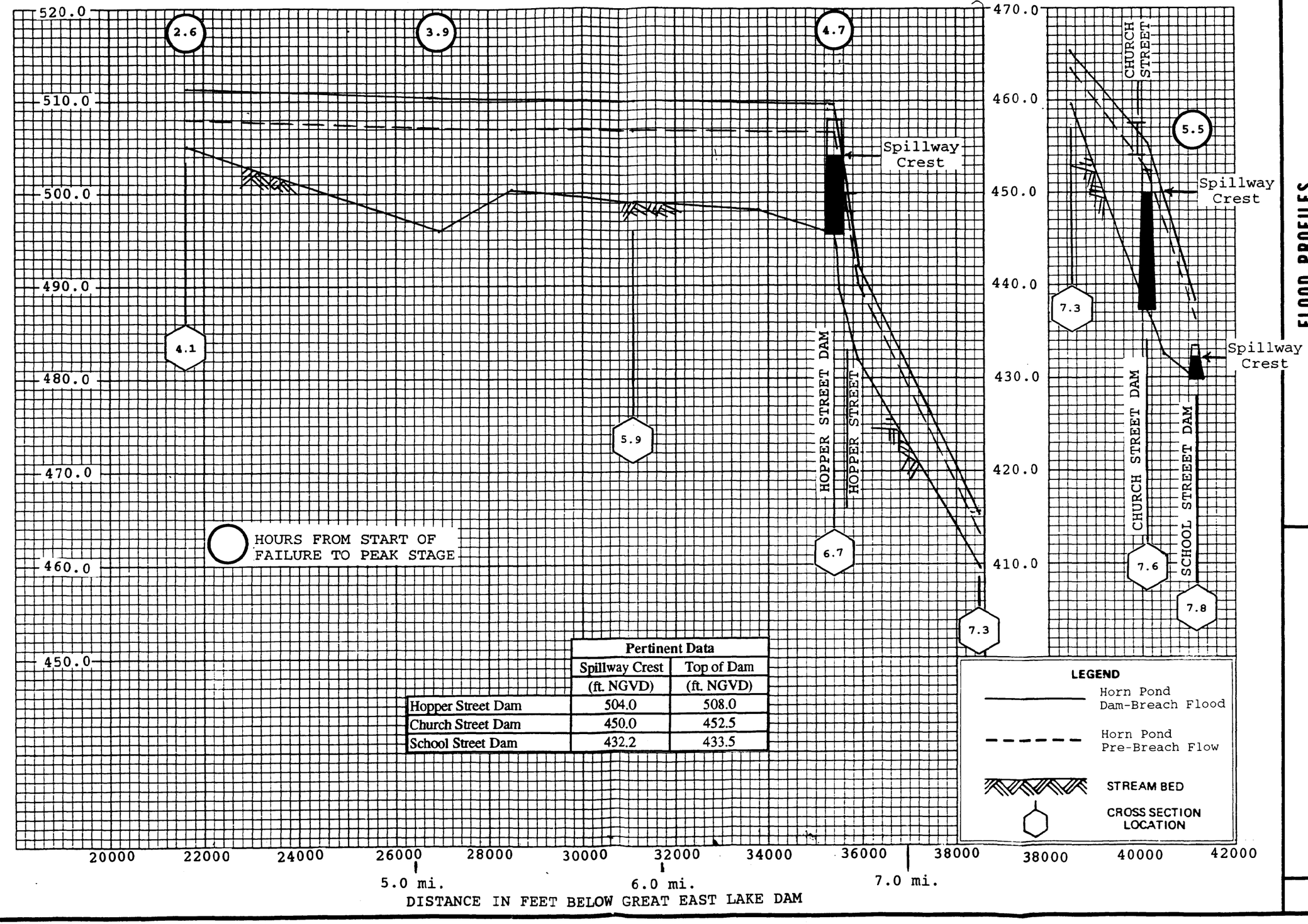
PLATE 4



Pertinent Data		
	Spillway Crest (ft. NGVD)	Top of Dam (ft. NGVD)
Hopper Street Dam	504.0	508.0
Church Street Dam	450.0	452.5
School Street Dam	432.2	433.5

FLOOD PROFILES

SALMON FALLS RIVER - PROFILE #2

HORN POND DAM
DAM-BREACH FLOOD ANALYSIS

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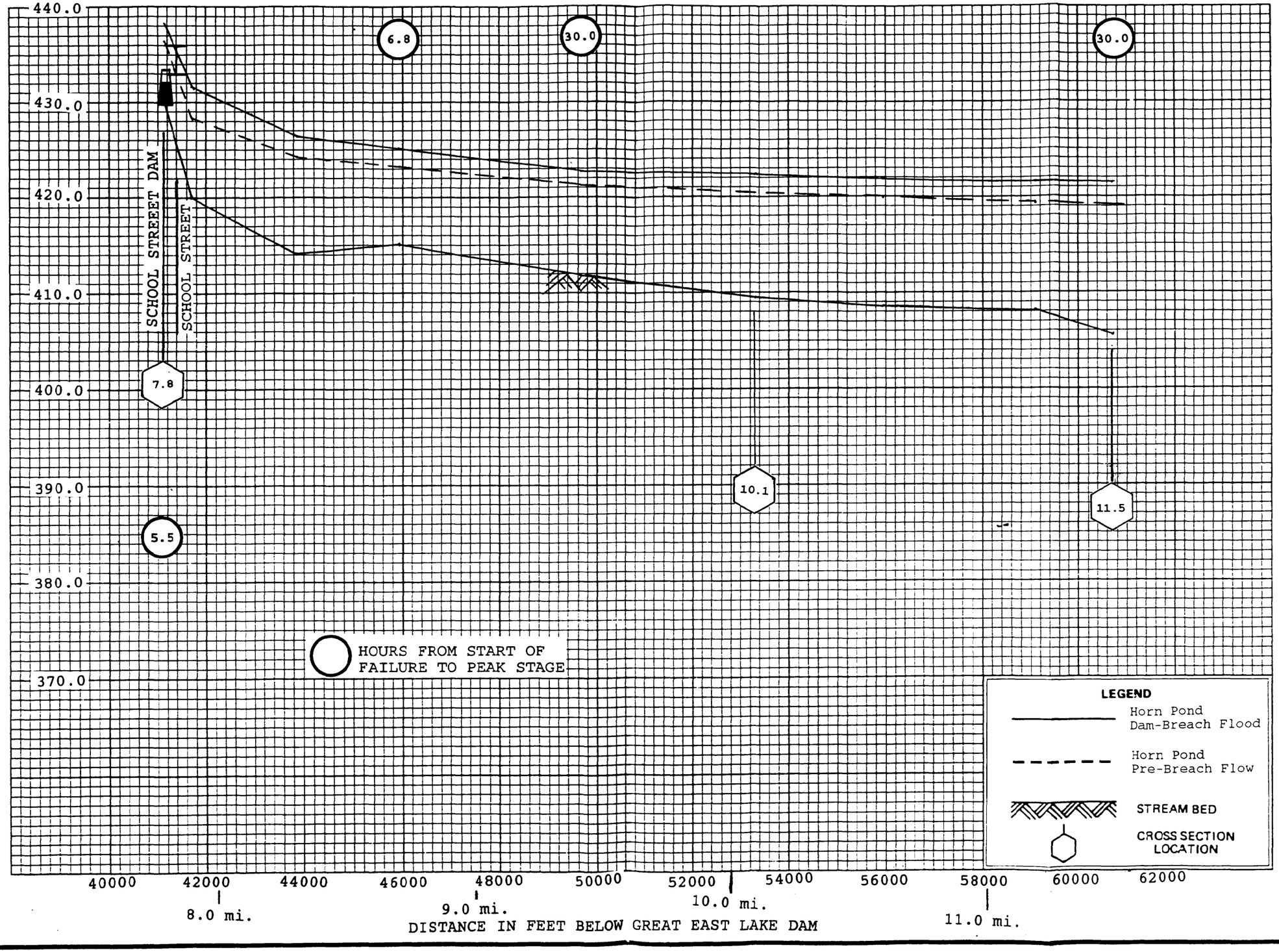
PLATE 5

FLOOD PROFILES

SALMON FALLS RIVER - PROFILE #3



HORN POND DAM
DAM-BREACH FLOOD ANALYSIS

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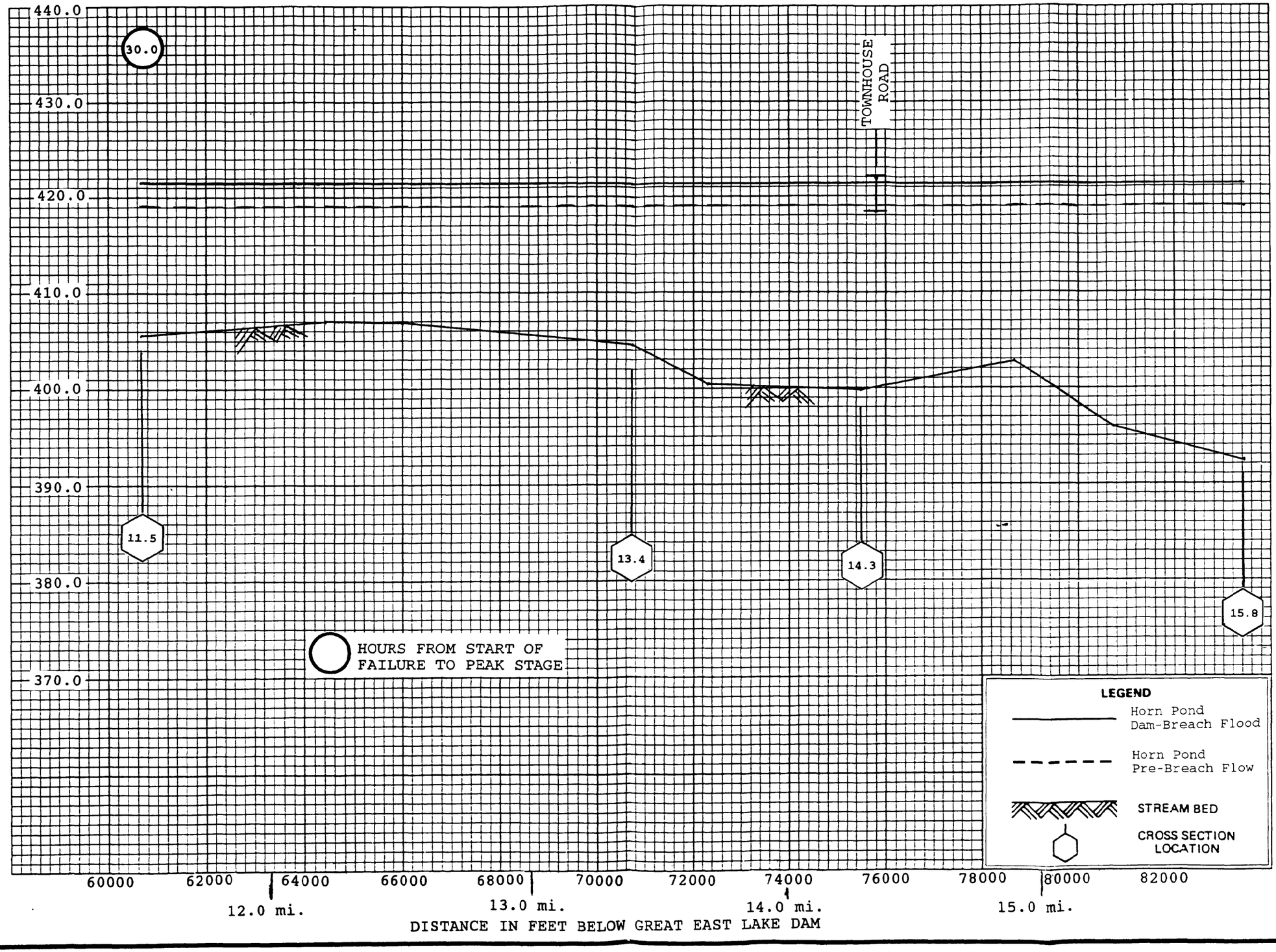
PLATE 6



FLOOD PROFILES

SALMON FALLS RIVER - PROFILE #4

HORN POND DAM
DAM-BREACH FLOOD ANALYSIS

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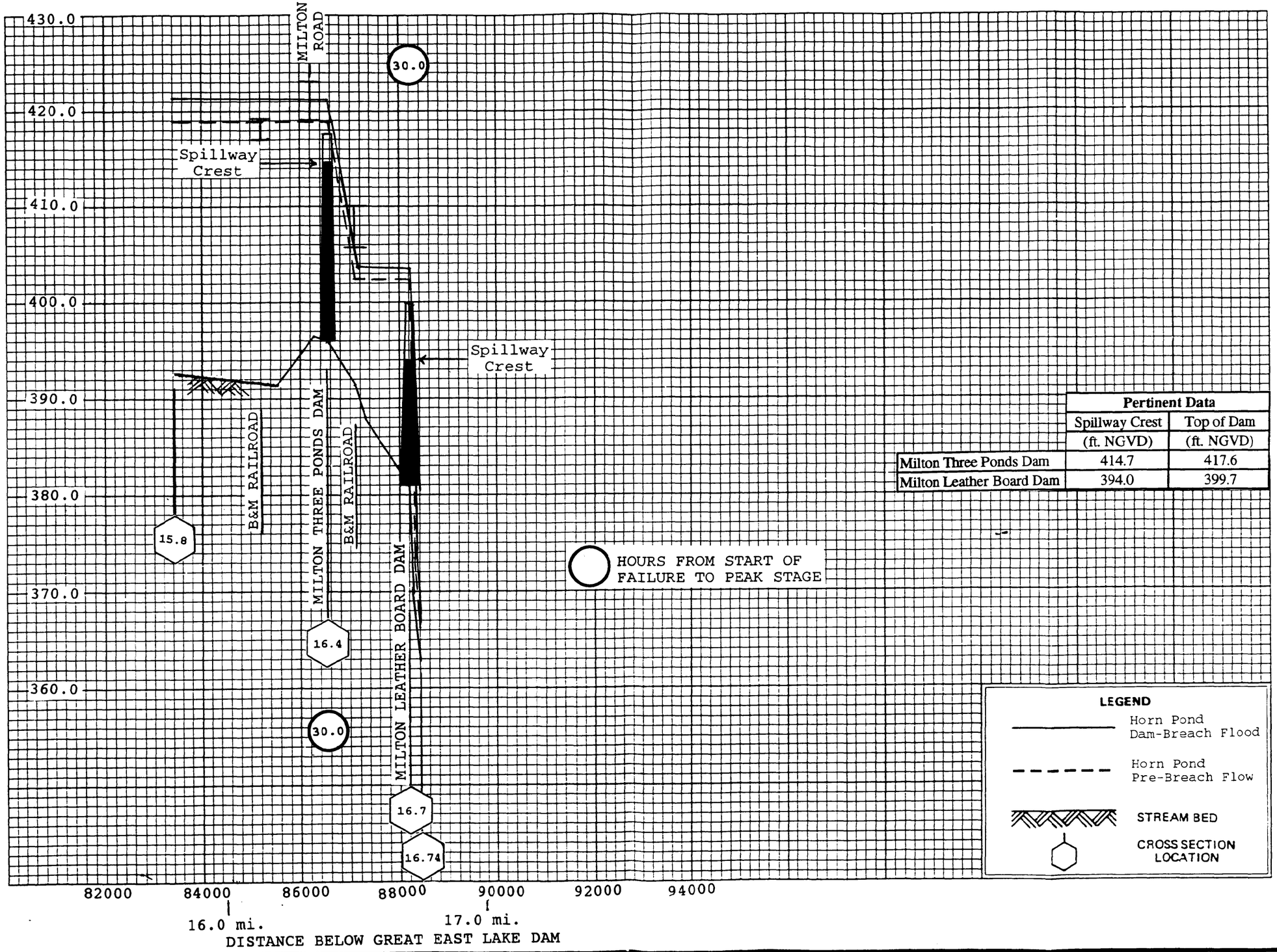
PLATE 7



Pertinent Data		
	Spillway Crest (ft. NGVD)	Top of Dam (ft. NGVD)
Milton Three Ponds Dam	414.7	417.6
Milton Leather Board Dam	394.0	399.7

FLOOD PROFILES

SALMON FALLS RIVER - PROFILE #5

HORN POND DAM
DAM-BREACH FLOOD ANALYSIS

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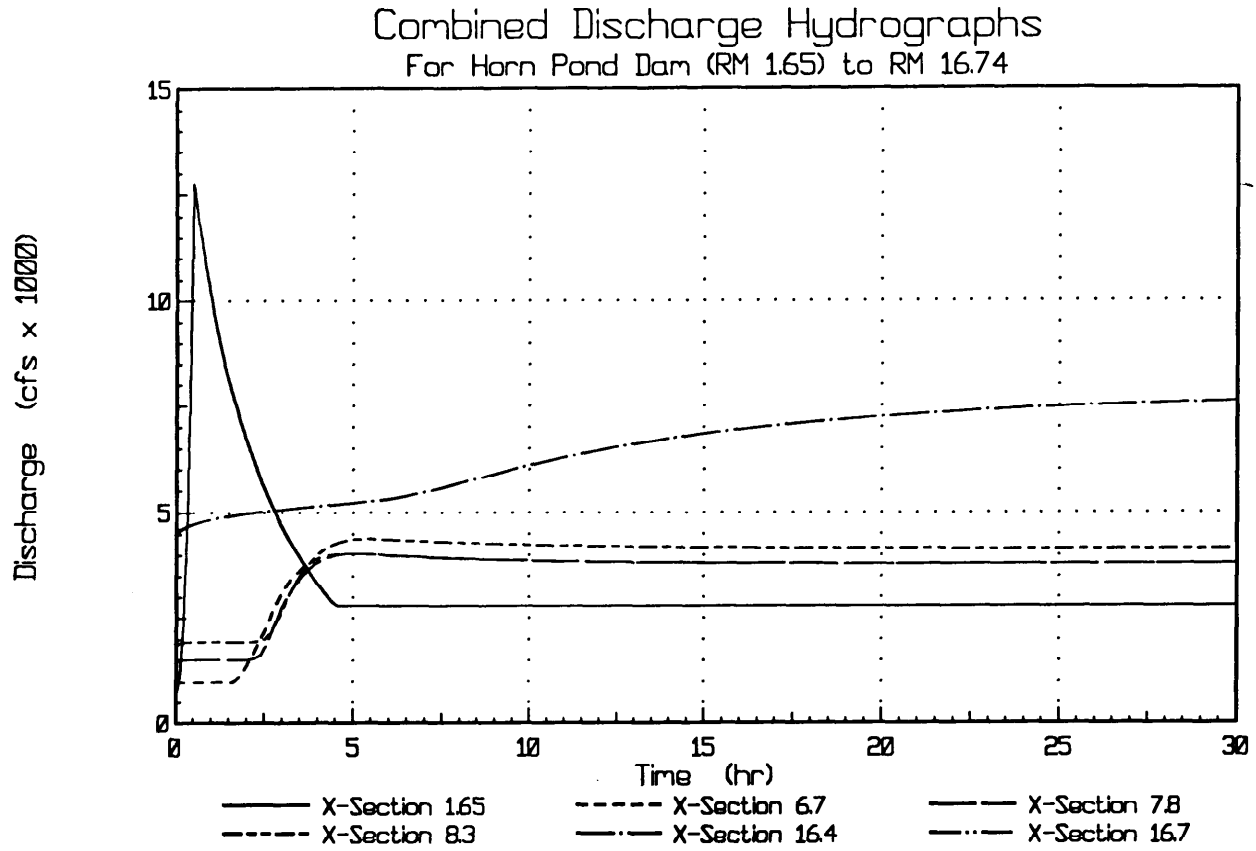
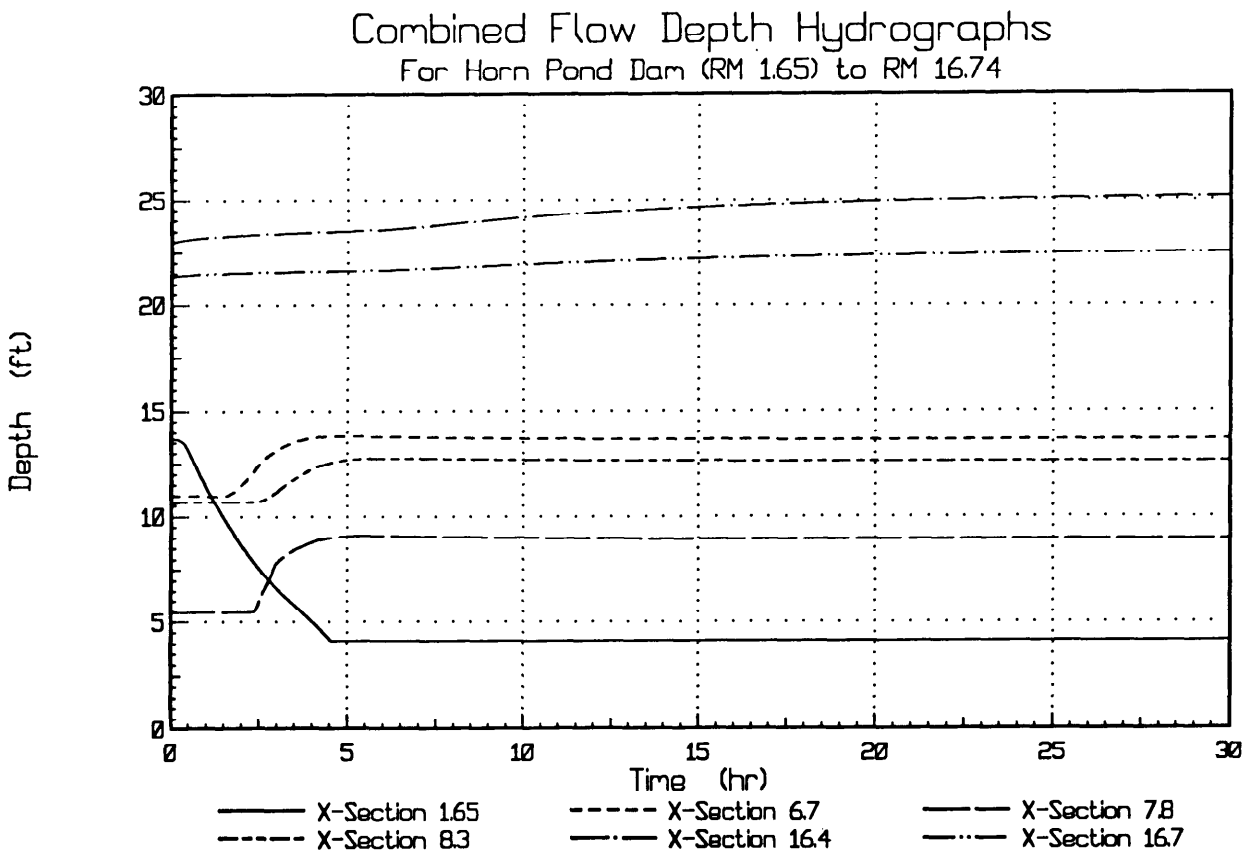
PLATE 8



Note: Start of Failure at 0.5 Hours.



Note: Start of Failure at 0.5 Hours.

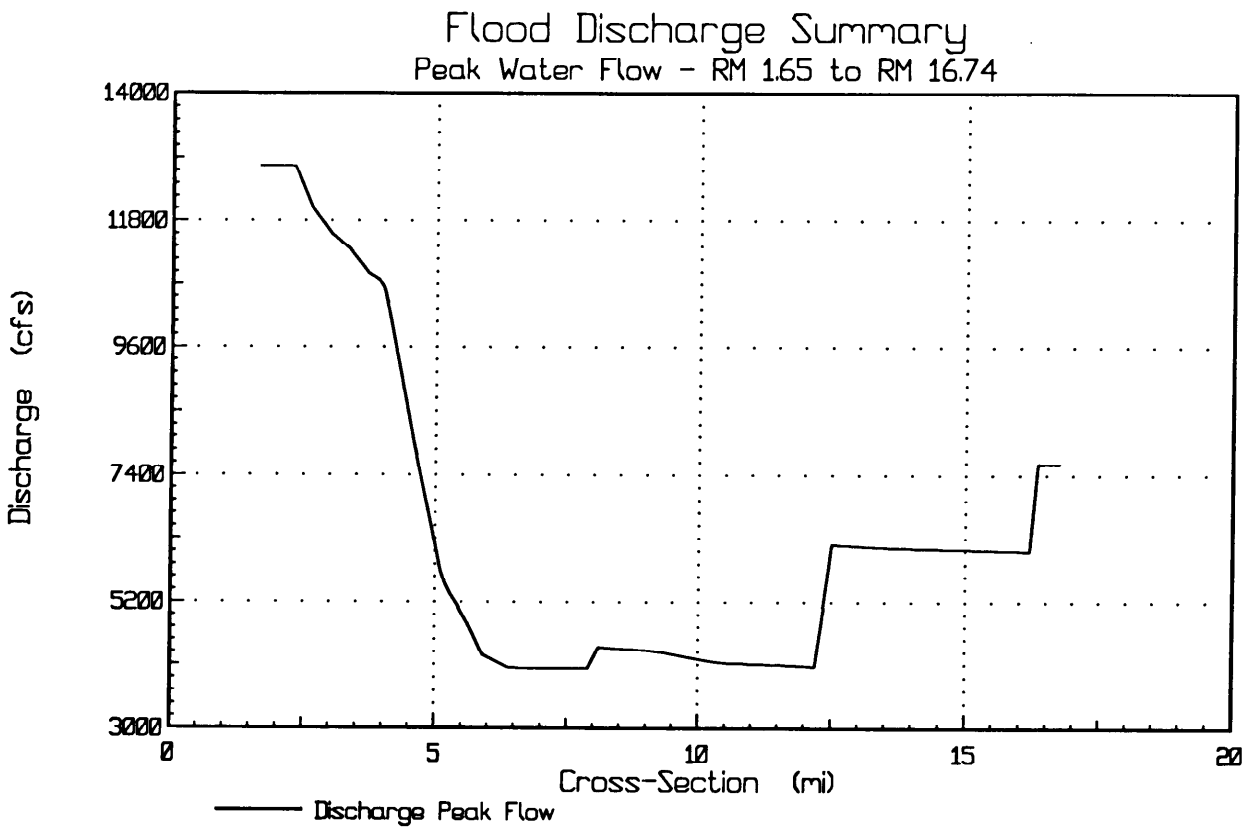

Flood Discharge Summary
Peak Water Flow - RM 1.65 to RM 16.74
14000
11800
9600
7400
5200
3000
Discharge (cfs)
0
5
10
15
20
Cross-Section (mi)
Discharge Peak Flow

PLATE 10

Appendix I:

Inundation Mapping